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(71) Applicant: MITSUBISHI JUKOGYO KABUSHIKI
KAISHA
5-1, Marunouchi 2-chome
Chiyoda-ku
Tokyo (JP)

(72) Inventor: Kishimoto, Kenji c/o Nagoya
Guidance & Propulsion
Sys. Works of Mitsubishi Jukogyo K.K., 1200
O-aza
Higashi Tanaka
Komaki-shi,

Aichi-ken (JP)

Inventor: Kakuma, Yojiro, c/o Nagoya

Guidance & Propulsion

Sys. Works of Mitsubishi Jukogyo K.K., 1200

O-aza

Higashi Tanaka,

Komaki-shi,

Aichi-ken (JP)

Inventor: Yasui, Masaaki, c/o Nagoya

Guidance & Propulsion

Sys. Works of Mitsubishi Jukogyo K.K., 1200

O-aza

Higashi Tanaka

Komaki-shi,

Aichi-ken (JP)

(74) Representative: Henkel, Feller, Hänzel &
Partner
Möhlstrasse 37
D-81675 München (DE)

(54) Expandable nozzle mechanism for a rocket engine.

(57) The upper stage (2) of a multi stage rocket has a high expansion bellmouth nozzle comprising a telescoping rear nozzle cone (5). This rear cone (5) is stored in a retracted position while the rocket is propelled by the lower stage(s) (1). The rear end of the rear cone (5) is releasably fixed to the front end

of the lower rocket stage (1). When the upper (1) and the lower rocket stage (2) are separated, the rear cone (5) is pulled into the extended operative position by the lower stage (1). After having locked in the extended position the rear cone (5) is released from the lower rocket stage (1).

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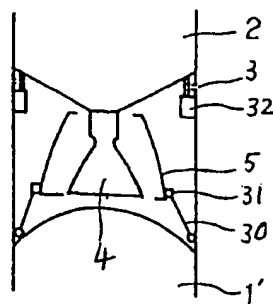


Fig. 8(A)

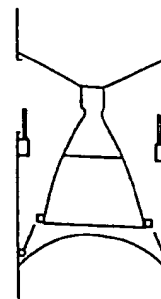


Fig. 8(B)

BACKGROUND OF THE INVENTION

TECHNICAL FIELD

The present invention relates to an expandable nozzle mechanism, with a high aperture ratio, which is small in size and light in weight, and which is retracted when the highly expandable nozzle is not used and is extended to a regular position when used, for a rocket engine with a high operational efficiency in a high altitude at which the ambient pressure is low, or aerospace.

BACKGROUND TECHNOLOGY

In order to effectively operate a rocket, which has been launched from the earth, in a high altitude space which is similar to the vacuum or in an aerospace, it is necessary to use an upper stage rocket engine provided with a nozzle having a high expandable ratio as exemplified in Fig. 12B.

The upper stage rocket engine which is to be used for propelling and controlling upper stage state rockets (second and third stages) at a high altitude or in an aerospace after the first stage rocket to be used for raising the rocket from the earth to the high altitude space has been released is long in length, and suffers from a spatial problem in transferring these upper stage rocket engines to the space where the engines are operated. In order to solve this problem, the upper stage rocket engine provided with the nozzle having a highly expandable ratio is separated at the nozzle portion back and forth, and the highly expandable nozzle which constitutes a rear half portion of the nozzle is forwardly pushed and telescopically retracted up to the vicinity of the rocket engine where a part of the nozzle remains. Thus, the transferring is carried out in a small volume. In operation, the highly expandable nozzle is extended rearwardly, and the nozzle is integrally formed with the nozzle portion remaining in the rocket engine for a highly expandable upper stage rocket engine.

The extension/contraction of the highly expandable nozzle has been conventionally carried out in the operational condition shown in the solid lines shown in Fig. 11. The highly expandable nozzle 01 is shifted to the rear portion of the rocket engine 04 which is the operational position, by a shifting device 03 such as a screw jack or a piston actuator to be driven hydraulically, pneumatically or electrically by a drive device 02 which is heavy in weight.

The conventional system needs a power source (not shown) such as a hydraulic pressure source, a gas source and an electric power source, the drive device 02 such as a hydraulic motor, a gas turbine, an electric motor and the like, and the

shifting device 03 such as an actuator, a screw jack, a piston or the like.

For this reason, not only the performance for launching the rocket is highly degraded but also would the rocket be drafted in a serpentine manner with dead weights of the components mounted on the upper stage rocket as far as these components are abolished, even after the operational mode for propelling and controlling the upper stage rocket is obtained by extending the highly expandable nozzle to the regular nozzle position. As a result, the mountable volume in the upper stage rocket is decreased, the weights are increased, and the load imposed to the upper stage rocket engine is increased, disadvantageously.

OBJECTS OF THE INVENTION

In order to overcome the above-described defects inherent in the conventional upper stage rocket engine, an object of the present invention is to provide an extendable nozzle mechanism for a rocket engine, which does not need a power device for extension and which may be operative by separating objects, to be separated and abolished in the propelling operation of the rocket, i.e., a lower stage rocket from an upper stage rocket engine transferred under the received condition.

SUMMARY OF THE INVENTION

As described above, the highly expandable nozzle is used in a highly vacuum ambient condition. In case of a launching rocket, it is used in the second stage rocket onward. In this case, during the operation of the first stage rocket, it is received in a body, and is extended during the separation of the first stage rocket. The separation of the first stage rocket is effected by imparting a momentum which is reversed to the travelling direction of the rocket, and the first stage rocket appears to be abolished relatively rearwardly as viewed from the second stage rocket.

The extendable nozzle mechanism for a rocket engine according to the present invention has the following arrangement for attaining the foregoing and other objects.

A coupling mechanism is provided at a front end portion of a lower stage rocket to be separated and abolished before operation of the upper stage rocket engine which use the highly expandable nozzle. A fastening portion for coupling the rear end of the highly expandable nozzle with the coupling mechanism of the lower stage rocket at a constant holding force from the retracted condition to the operative condition is provided at a rear end of the highly expandable nozzle which is the rear half portion of the upper stage rocket engine di-

vided back and forth at the nozzle portion. A small diameter portion is provided at a front end portion of the highly expandable nozzle portion for generating a brake force by the coupling between the coupling mechanism and the fastening portion by contacting with the outer periphery of the rocket engine which is a front half portion of the upper stage rocket engine when the highly expandable nozzle is shifted rearwardly while following the rearward movement of the separated lower stage rocket, and for generating the braking force, greater than the coupling force between the coupling mechanism and the fastening portion, when the rearward movement of the highly expandable nozzle reaches a predetermined value. A coupling wall connected to the small diameter portion of the highly expandable nozzle when the coupling between the highly expandable nozzle that moved rearwardly along the outer peripheral wall and the lower stage rocket is released and a latch mechanism coupled to the coupling wall for limiting the forward movement of the highly expandable nozzle are provided.

With such an arrangement, the highly expandable nozzle coupled at its front end portion to the rear end portion of the rocket engine to form the upper stage rocket engine having a highly expandable ratio is separated and is shifted rearwardly together with the lower stage rocket that moves rearwardly by the separation from the upper stage rocket from the received condition around the rocket engine. In the rear side of the rocket engine from which the highly expandable nozzle is separated, the nozzle portion which is expanded rearwardly is left, and the small diameter portion provided at the front end portion of the highly expandable nozzle is moved rearwardly in sliding contact with the outer periphery of the nozzle portion. However, as the diameter of the nozzle portion is increased, the frictional force of the sliding portion is increased. Finally, the frictional force exceeds the coupling force between the coupling mechanism of the lower stage rocket and the fastening portion of the highly expandable nozzle so that the coupling between the lower stage rocket and the highly expandable nozzle is released. A coupling wall to be engaged with the small diameter portion of the highly expandable nozzle that has travelled rearwardly is provided on the outer periphery of the nozzle portion at which the coupling is released. Simultaneously with the release of coupling between the lower stage rocket and the highly expandable nozzle, the rocket engine and the highly expandable nozzle are coupled to each other to form the upper stage rocket engine having a high expandable ratio.

Furthermore, after the coupling between the rocket engine and the highly expandable nozzle,

the forward movement of the highly expandable nozzle caused by the coupling shock is limited by the latch mechanism provided on the outer circumferential wall of the nozzle portion, and the re-separation is prevented.

Thus, it is possible to dispense with the power source, drive source or actuator which has a large weight and was needed for extension of the nozzle in the conventional rocket system. Also, without any specific coupling release mechanism, the coupling mechanism is abolished together with the lower stage rocket. It is unnecessary to increase the load imposed on the upper stage rocket engine to overcome the problems inherent in the conventional system. Also, the coupling mechanism and the fastening portion for coupling the highly expandable nozzle and the lower stage nozzle are also used as a fastening and supporting mechanism for the highly expandable nozzle during the operation of the lower stage rocket engine. Thus, an unnecessary support mechanism may be dispensed with.

Also, the coupling mechanism according to the present invention may include a support which is made of elastic material for increasing the sliding frictional force at least at the outer circumferential edge fixed and arranged in an annular shape at the front end portion of the lower stage rocket. The fastening portion may be the inner circumferential wall at the rear end of the highly expandable nozzle engaged with the outer circumferential edge of the support.

Thus, the coupling between the suitable lower stage rocket and the highly expansion nozzle may be generated by the frictional force between the inner circumferential wall at the rear end of the highly expandable nozzle and the outer circumferential edge of the support to thereby dispense with the support mechanism for the highly expandable nozzle in the received condition. Also, since it is possible to effect the coupling only by the inner circumferential wall with the support, to thereby reduce the weight and to thereby facilitate the manufacture.

Furthermore, by using the elastic material for the support, it is possible to obtain a desired frictional force and also to prevent the vibration, that is generated during the operation of the lower stage rocket engine, from reaching the highly expandable nozzle.

The coupling mechanism may be a support in which a grooved member made of elastic material is arranged in an annular shape in the outer circumferential edge in the front end portion of the lower stage rocket. The fastening portion is inserted into the grooved support. The fastening portion may be the inner and outer circumferential walls of the rear end circumferential edge of the

highly expandable nozzle which receives a compression force from both sides of the groove. Thus, it is possible to obtain the same effect and advantage as those in the case where the coupling mechanism is the support made of elastic material. In addition, the coupling force between the grooved support and the rear end inner circumferential wall of the highly expandable nozzle is increased. It is possible to positively effect the holding action of the highly expandable nozzle in the retracted condition.

Also, the coupling mechanism may be a clamping mechanism including two rods pivoted at first ends to the front end portion of the lower stage rocket, rollers provided at second ends of the rods and a spring member interposed between central portions of the rods said fastening portion being inner and outer circumferential walls of the rear end circumferential edge of the highly expandable nozzle inserted in between the rollers of said clamping mechanism.

With such an arrangement, it is possible to control the coupling force between the highly expandable nozzle and the lower stage rocket only by selection of the spring member as desired. Also, it is unnecessary to provide the fastening portion of the highly expandable nozzle over the entire circumference of the rear end circumferential edge. It is possible to reduce the weight of the highly expandable nozzle in addition to the reduction of the weight of the coupling mechanism and the releasing mechanism.

Also, in the coupling mechanism, it is possible to use a coupling bracket which is fixed at one end to the front end portion of the lower stage rocket and which is provided with cut slits for avoiding the adverse affect to the other portions by cutting the coupling bracket at the cut slits when the load which exceeds a limit is applied to the central portion of the coupling bracket.

By this arrangement, it is possible to simplify the coupling between the highly expandable nozzle and the lower stage rocket. It is possible to produce the coupling mechanism at a low cost and to positively separate it by a predetermined load by controlling the cut slits. Also, it is possible to reduce a weight of the highly expandable nozzle.

Also, in the extendable nozzle mechanism for a rocket engine according to the invention, the highly expandable nozzle is coupled through wires to an object, to be separated and abolished during the propelling operation of the rocket, such as a lower stage rocket. The highly expandable nozzle is extended to a regular position by utilizing a momentum which is caused by the rearward movement of the object to be separated and abolished.

The tension direction of the wires may be suitably controlled by providing pulleys or guides

for guiding the wires which are drawn in accordance with the rearward movement of the object to be separated and abolished. The displacement may be prevented. By the cutting mechanism for cutting the first stage rocket rearwardly, the wires are cut at the time when the nozzle has been shifted to the regular position.

It is possible to use a wire cutter or the like for cutting the coupling portion of the wires and the highly expandable nozzle by using gun powder.

Thus, the highly expandable nozzle is extended by utilizing the force caused by the rearward movement of the wires as the object to be separated and abolished during the propelling operation of the rocket, such as a lower stage rocket is moved rearwardly. Accordingly, it is unnecessary to use an independent power source for extension of the highly expandable nozzle. In addition, the wires have a very small weight for drawing the highly expandable nozzle as a drive actuator.

After the highly expandable nozzle is extended, the wires are cut. The wires are abolished rearwardly together with the object to be separated and abolished such as the first stage rocket. It is unnecessary to use the drive mechanism except for the part of pulley on the rocket body side after the extension of the highly expandable nozzle. Accordingly, the extendable nozzle mechanism for a rocket engine according to the present invention may be effectively applied to the reduction or miniaturization of the rocket.

Also, in the extendable nozzle mechanism for a rocket engine according to the invention, guide rails in parallel with said engine are provided to at least one of a rear end portion of an upper stage rocket on which the rocket engine is mounted and an end portion of an object such as a lower stage rocket to be separated or abolished, and travelling rollers which travel along the guide rails are provided on the other. Thus, the highly expandable nozzle received in the retracted condition may be moved exactly rearwardly in alignment with the axial direction of the upper stage rocket and the rocket engine. The local abutment of the highly expandable nozzle against the nozzle portion outer periphery may be prevented. The highly expandable nozzle may be guided exactly and coupled at the coupling position of the nozzle portion. It is also possible to prevent the contact accidents from occurring with the lower stage rocket that has been released.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

Fig. 1A is a cross-sectional view showing a separation part between an upper stage rocket and a lower stage rocket according to a first

embodiment of the invention before separation;
Fig. 1B is a cross-sectional view at a certain timing after the separation;

Fig. 2 is a partial cross-sectional view showing a coupling condition between a nozzle portion rear end and a highly expandable nozzle small diameter portion according to the embodiment shown in Figs. 1A and 1B;

Fig. 3A is a side elevational sectional view showing a guide device for guiding the lower stage rocket and the highly expandable nozzle rearwardly before the separation of the lower stage rocket in the separation part between the upper stage rocket and the lower stage rocket according to a second embodiment of the invention;

Fig. 3B is a side elevational sectional view showing the state where the highly expansion nozzle is coupled with the nozzle portion;

Fig. 4A is a partial sectional view showing the coupling mechanism and the fastening portion shown in Figs. 1A and 1B before the separation according to a third embodiment of the invention;

Fig. 4B is a partial sectional view showing the coupling mechanism and the fastening portion shown in Figs. 1A and 1B after the separation;

Fig. 5A is a partial sectional view showing the coupling mechanism and the fastening portion shown in Figs. 1A and 1B before the separation according to a fourth embodiment of the invention;

Fig. 5B is a partial sectional view showing the coupling mechanism and the fastening portion shown in Figs. 1A and 1B after the separation;

Fig. 6A is a partial sectional view showing the coupling mechanism and the fastening portion shown in Figs. 1A and 1B before the separation according to a fifth embodiment of the invention;

Fig. 6B is a partial sectional view showing the coupling mechanism and the fastening portion shown in Figs. 1A and 1B after the separation;

Fig. 7A is a partial sectional view showing the coupling mechanism and the fastening portion shown in Figs. 1A and 1B before the separation according to a sixth embodiment of the invention;

Fig. 7B is a partial sectional view showing the coupling mechanism and the fastening portion shown in Figs. 1A and 1B after the separation;

Figs. 8A and 8B are views showing the state of the separation part between the upper stage rocket and the lower stage rocket according to a seventh embodiment, Fig. 8A being a cross-sectional view showing the highly expandable nozzle before extension, and Fig. 8B being a cross-sectional view showing the highly expandable nozzle after extension;

Figs. 9A and 9B are views showing the state of the separation part between the upper stage rocket and the lower stage rocket according to an eighth embodiment, Fig. 9A being a cross-sectional view showing the highly expandable nozzle before extension, and Fig. 9B being a cross-sectional view showing the highly expandable nozzle after extension;

Figs. 10A and 10B are views showing the state of the separation part between the upper stage rocket and the lower stage rocket according to a ninth embodiment, Fig. 10A being a cross-sectional view showing the highly expandable nozzle before extension, and Fig. 10B being a cross-sectional view showing the highly expandable nozzle after extension;

Fig. 11 is a side elevational sectional view showing an example of a conventional extendable nozzle mechanism for a rocket engine; and

Figs. 12A and 12B are perspective views showing upper stage rocket engines, Fig. 12A showing an upper stage rocket engine having no extendable nozzle, and Fig. 12B showing an upper stage rocket engine having an extendable nozzle.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will now be described with reference to the accompanying drawings.

As shown in Fig. 1A, a lower stage rocket 1 and an upper stage rocket 2 are coupled with each other by a coupler 3 having the same outside diameter as that of the upper and lower stage rockets 2 and 1. The upper and lower stage rockets are launched up to a high altitude space by the lower stage rocket engine (not shown) provided at an end of the lower stage rocket 1. In order to effectively operate the upper stage rocket engine, which is to be used in a high altitude space whose ambient pressure is similar to the vacuum, it is necessary to use the upper stage rocket engine having a highly expandable ratio. The latter is very long in length at about 5m.

For this reason, the upper stage rocket engine is separated at a nozzle portion 6 of a rocket engine 4 into the rocket engine 4 and a highly expandable nozzle 5 back and forth. The highly expandable nozzle 5 is raised around an outer periphery of the rocket engine 4 and is contracted to a length of about three fifths. The nozzle 5 is accommodated in a gap portion defined between a rear end of the upper stage rocket 2 and a tip end of the lower stage rocket 1 and transferred to the highly altitude space. It is thus possible to reduce the length of the gap, and reduce the weight by about 100 kg. An inner circumferential wall of a

rear end portion of the highly expandable nozzle 5 as a fastening portion is inserted into and coupled with a support 7, as an annular coupling means, formed of an elastic material such as rubber, fixed to the tip end of the lower stage rocket 1 and having a high friction coefficient for absorber. The support 7 has substantially the same configuration as that of an outlet portion (i.e., rear end portion) as a fastening portion for the highly expandable nozzle 5 and has an outer configuration of a truncated cone shape which is approximately larger than the inner circumferential shape of the rear end thereof. The rear end portion of the highly expandable nozzle 5 is pressingly inserted into the support 7 upon assembling the rocket.

When the combustion of the lower stage rocket engine mounted at the rear end of the lower stage rocket 1 is terminated, the lower stage rocket 1 is released from the upper stage rocket 2 and abolished because it interferes with the mission. This abolishment is carried out by imparting a motion, that is reversed to the advance direction, to the lower stage rocket 1 and by the rearward movement of the lower stage rocket 1. The highly extendable nozzle 5 which is kept under the pressing insertion condition while being inserted into the support 7 is also moved rearwardly together with the lower stage rocket 1 as shown in Fig. 1B. The rearward movement of the highly expandable nozzle 5 is carried out by the operation in which the nozzle 5 is moved rearwardly along the outer circumferential portion of the rocket engine 4 and in an axial direction of the upper stage rocket 2 and the lower stage rocket 1. When a small diameter portion provided in the front end portion of the nozzle 5 reaches a latch mechanism 15, to be described later, provided on the outer circumferential portion of the nozzle portion 6 of the rocket engine 4, the rearward force is braked by a frictional force between the latch mechanism 15 and the small diameter portion 8 but an inertia of the lower stage rocket is large to continue the rearward movement. At a position where the front end portion has just passed through the latch mechanism 15, the small diameter portion 8 is brought into sliding contact with the engagement surface 9 which has a larger diameter than that of the latch portion 15. A larger frictional force than the coupling force between the support 7 and the inner circumferential surface of the rear edge portion coupled with the support portion for coupling the highly expandable nozzle 5 and the lower stage rocket 1 is generated, so that the coupling is released to thereby divide the highly expandable nozzle 5 away from the lower stage rocket 1.

As described above, the coupling between the fastening portion which is the rear end inner circumferential wall of the highly expandable nozzle

and the support used as a coupling device provided at the tip end of the lower stage rocket is defined by a gradient for releasing, and in addition, is effected only by the coupling force of the friction force. Accordingly, the coupling may readily be attained. When the coupling is released, the highly expandable nozzle 5 is fixed under the condition that the small diameter portion 8 thereof is brought into sliding contact with the coupling surface 9 formed on the outer circumferential wall of the nozzle portion 6. The lower stage rocket 1 solely is moved and separated for abolishment. Thus, the operational condition is attained by utilizing the movement of the lower stage rocket 1 which is to abolish the highly expandable nozzle 5 kept under an accommodation condition, without needs to use the power source, the drive source and any other special shifting device. As a result, it is possible to attain the weight reduction of about 20 to 30 kg.

Subsequently, the coupling portion among the latch mechanism 15, the nozzle portion 6 and the highly expandable nozzle 5 will be explained.

A ring 10 is fixed over the entire circumference at the rear outer circumferential portion of the nozzle portion 6. The coupling surface 9 is formed on the outer circumferential wall of the ring 10. Furthermore, the latch mechanism 15 is provided at an equal interval over the entire circumference of the nozzle portion 6 in front of the ring 10. Each latch mechanism 15 is composed of a hinge 12 provided on the outer circumferential wall of the nozzle portion 6, a lever 13 pivoted to the hinge 12, a spring 14 interposed between the lower stage surface and the outer circumferential wall of the nozzle portion 6 for imparting an outward force to the lever 13, and a stopper 16 for preventing the jump-up action of the lever 13.

As described above, the highly expandable nozzle 5 coupled to the lower stage rocket 1 is moved rearwardly, and moved while pushing the lever 13 by the inner circumferential wall of the small diameter portion 8 formed at the front end portion of the highly expandable nozzle 5. At the time when the front edge of the small diameter portion 8 has passed through the rear end of the lever to complete the movement, the lever 13 is released. As a result, the lever 13 is expanded outwardly by the force of the spring 14 to prevent again the movement in a reverse direction (i.e., the forward direction) of the highly expandable nozzle.

On the other hand, the inner circumferential wall of the small diameter portion 8 which has passed through the lever 13 is moved toward the coupling surface 9 of the ring 10 having a larger diameter than a diameter defined by the lever 13 under the condition that the lever 13 is pushed downwardly by the spring 14, whereby the frictional force of the sliding portion therebetween is in-

creased abruptly, and the coupling between the rear edge of the highly expandable nozzle and the front edge portion of the lower stage rocket is released. The small diameter portion 8 remains under the condition it is brought into sliding contact with the coupling surface 9 without any modification. The small diameter portion 8 is coupled with the coupling surface 9. Incidentally, a seal material 17 is applied in advance to the coupling surface. The leakage of the gas between the coupling surface 9 and the small diameter portion 8 is sealed by the seal material 17.

A guide device for exactly guiding the highly expandable nozzle 5, which is moved rearwardly together with the lower stage rocket 1 during the separation of the lower stage rocket 1, in the axial direction of the rocket engine 4 will now be described with reference to Fig. 3.

Three or more guide rails 18 are provided at an equal interval rearwardly in parallel with the body axis of the upper stage rocket 2 on an inner circumferential wall of an outer plate at the rear end of the upper stage rocket. On the other hand, a plurality of travelling rollers 19 which travel on the guide rails 18 are provided on the inner circumferential wall of the outer plate at the front edge of the lower stage rocket 1 at positions corresponding to the guide rails 18. Accordingly, in the case where the accommodation condition of the highly expandable nozzle 5 shown in Fig. 3A is changed to the operational condition shown in Fig. 3B, the highly expandable nozzle 5 is moved rearwardly along the axis of the upper stage rocket 2 (i.e., an axis of the rocket engine 3). Thus, it is possible to align the coupling surface 9 and the small diameter portion 8 formed in the nozzle portion 6 without any twist phenomenon.

It is of course possible to provide the travelling rollers at the rear end portion of the upper stage rocket 2 and to provide the guide rails at the front edge portion of the lower stage rocket 1.

In the foregoing embodiment, the guide device is provided as shown in Fig. 1, but it is possible to ensure the same effect in any of the other embodiments to be described later.

Figs. 4A and 4B are cross-sectional views showing another embodiment in which a support is used as a coupling device at the front edge of the lower stage rocket 1.

The support is composed of a body portion 20 fixed to the lower stage rocket 1 and a coupling portion 21 which is made of elastic material and which coats the circumferential edge portion of the body portion 20. The configuration and effect of the support are the same as those of the above-described support 7. However, the support (composed of a body portion 20 and a coupling portion 21) has an advantage that it may be light in weight

in comparison with the former support 7.

Figs. 5A and 5B show a grooved support 24 in which, in order to more positively ensure the coupling between the highly expandable nozzle 5 and the lower stage rocket 1 than that in the foregoing embodiment, an outer circumferential support damper 22 is provided over an entire circumferential or a part on the outer wall side of the highly expandable nozzle 5 in addition to the above-described truncated conical support 21 which is engaged with the fastening portion at the inner wall of the highly expandable nozzle 5, thereby form a groove 23. The fastening portion of the which is defined by the rear end inner circumferential wall of the highly expandable nozzle 5 is inserted into the groove so as to be clamped.

Incidentally, in this embodiment, it is preferable to facilitate the release of the coupling by forming the outer circumferential support damper 22 on the outer wall side of the grooved support 24 substantially into a cylindrical wall, or making it in a collapsible fashion or imparting a flexibility to it without completely pressing it by the conical wall.

Figs. 6A and 6B show an easy coupling/releasing mechanism between the highly expandable nozzle 5 and the lower stage rocket 1 by using a clamping mechanism 25 provided with rollers 26 instead of the supports 7, 21 or the grooved support 24 used in the foregoing embodiments.

The clamping mechanism 25 is composed of two rods 27 each having a proximal end pivoted coaxially with a horizontal shaft at the tip end portion of the lower stage rocket 1, rollers 26 provided at respective distal ends of the rods 27, and a spring member 28 interposed between the central portions of the rods 27 for imparting a fastening force to the rods 27.

In the clamping mechanism 25, the fastening portion provided at the rear end of the highly expandable nozzle 5 inserted between the rollers 26 is always pressed and fastened from the inside and the outside by the spring force. Upon the separation of the lower stage rocket 1, the lower stage rocket 1 is shifted rearwardly, and at this time, the highly expandable nozzle 5 is shifted rearwardly to the regular position together with the lower stage rocket 1 while being clamped by the clamping mechanism 25. When the highly expandable nozzle 5 is held at the regular position, only the lower stage rocket 1 is shifted rearwardly. At this time, the clamping mechanism 25 is separated rearwardly along with the conical wall of the highly expandable nozzle 5 while clamping the fastening portion of the highly expandable nozzle 5 from the inside and outside by the movable mechanism of the rods 27. With this clamping mechanism 25, it is possible to easily release and couple the separa-

tion nozzle 5 and the lower stage rocket 1 but also to easily effect the coupling of the highly expandable nozzle 5 with nozzle portion 6.

Furthermore, in this embodiment, it is possible to set the desired coupling force by suitably selecting the spring member 28. The supporting (holding) of the highly expandable nozzle 5 may be carried out in the retracted state without fail. In addition, upon the release from the lower stage rocket 1, the release action may be carried out in an exact state. Also, it is unnecessary to provide the fastening portion over the entire circumference of the rear end of the highly expandable nozzle. It is sufficient to enhance the mechanical strength only at the fastening portion which is to be inserted between the rollers 26. Thus, it is possible to reduce a weight of the highly expandable nozzle 5.

In Figs. 7A and 7B, the lower stage rocket 1 and the highly expandable nozzle 5 are coupled with each other by a coupling bracket 29, and the highly expandable nozzle 5 is coupled with the nozzle portion 6 of the rocket engine 4 by the rearward shift of the lower stage rocket 1 after the highly expandable nozzle 5 has been shifted rearwardly to a regular extendable position. In the coupling bracket 29, there is provided a mechanically weak portion, i.e., cut groove from which the bracket is divided. As a result, it is possible to positively carry out the separation with a predetermined load and also to carry out the coupling between the lower stage rocket 1 and the highly expandable nozzle 5 with a simple mechanism. It is also possible to reduce the weight of the highly expandable nozzle. Incidentally, the coupling bracket 29 may be formed in a wire-like member.

Figs. 8A and 8B show an embodiment in which the lower stage rocket 1' and the highly expandable nozzle 5 are directly coupled with each other by wires 30. As shown in Fig. 8A, the highly expandable nozzle 5 is received in a retracted state around the rocket engine 4, and the rear end of the highly expandable nozzle 5 is coupled with the lower stage rocket 1' by the wires 30. Reference numeral 31 designates a wire cutter using, for example, gun powder. The cutters are mounted on the outer wall of the rear end portion of the highly expandable nozzle 5. Reference numeral 32 denotes a separation mechanism.

In the rocket shown in Figs. 8A and 8B, when the first stage rocket 1' has been completely burnt after the launching operation of the rocket, the first and second stage rockets are separated so that the first stage rocket is shifted rearwardly. The expandable nozzle 5 coupled to the first stage rocket 1' by the wires 30 is drawn by the first stage rocket 1' from the retracted position. When the expandable nozzle 5 is shifted to the coupling position with the engine body 4, the wire cutters 31 are operated to

cut the wires 30 to complete the shift of the highly expandable nozzle 5. The condition upon the separation is shown in Fig. 8B.

Figs. 9A and 9B show another embodiment. As shown in Fig. 9A, wires 30 connected to the highly expandable nozzle 5 through wire cutting mechanisms 31 are guided by a plurality of pulleys 33 and connected to the first stage rocket 1'.

In this embodiment, during the retraction and expansion of the highly expandable nozzle 5, the wires 30 always keep the extended condition and the tension applied to the wires 30 during the expansion is kept uniform. As a result, the slant or tilt of the highly expandable nozzle 5 is prevented during the expansion operation.

Also, there is no entanglement of the wires 30 during the expansion and retraction of the highly expandable nozzle 5.

The other structure and effect are the same as those in the embodiment shown in Figs. 8A and 8B.

In another embodiment shown in Figs. 10A and 10B, a plurality of wires 30 coupled to a plurality of positions of the highly expandable nozzle 5 are bundled at one position 34 and thereafter are connected at one position to the first stage rocket 1' through the wire cutting mechanism 32.

In the case where the first stage rocket 1' is drawn from the plurality positions of the first stage rocket 1' by the plurality of wires 30 as shown in Figs. 8A, 8B, and 9A, 9B, there is a fear that the tension for drawing the highly expandable nozzle 5 would be non-uniform when the first stage rocket 1' is slanted. In order to avoid this defect, the coupling point 34 between the wires 30 and the first stage rocket 1' is limited to one position.

Since the wires are branched into a plurality of wires within an interior of the rear end portion of the upper stage rocket 2, the highly expansion nozzle 5 may be uniformly tensioned. Also, with such an arrangement, a single cutting mechanism 32 suffices.

The other structure and effect of this embodiment are the same as those shown in Figs. 8A, 8B and 9A, 9B.

Various details of the invention may be changed without departing from its spirit nor its scope. Furthermore, the foregoing description of the embodiments according to the present invention is provided for the purpose of illustration only, and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

As described above in detail, according to the present invention, the highly expandable nozzle is formed in an extendable type to thereby reduce a space for receiving the upper stage rocket engine and to reduce a weight of the body. For example,

in case of an engine having a diameter of 4 m and a length of 5 m, if the length may be reduced to 3 m, it is possible to reduce a weight of the body by amount 100 kg.

Also, since for expanding the retracted nozzle, the highly expandable nozzle is expanded by using a momentum of the separated and abolished object, there is no needs to provide special drive source, power source or shifting device. This makes it possible to simplify the structure and to enhance the reliability. Also, the weight may be reduced by about 20 to 30 kg in comparison with other system. In particular, according to the invention, it is possible to reduce a weight of the upper stage rocket, which leads to an improvement of the launching performance.

Also, since a special device for supporting the highly expandable nozzle in a retracted condition may be dispensed with, the launching performance of the rocket is largely improved. The coupling mechanism for coupling the highly expandable nozzle and the lower stage rocket does not need a special separation device. The coupling mechanism is abolished together with the lower stage rocket. Therefore, the performance of the upper stage rocket may be improved.

Claims

1. An extendable nozzle mechanism for a rocket engine, used for separating from said rocket engine 4 a highly expandable nozzle 5 coupled at a front end portion to a rear end portion of said rocket engine 4 and bringing a retracted condition where said highly expandable nozzle 5 is loosely engaged around an outer periphery of said rocket engine 4 into an operative condition where an upper stage rocket 2 is propelled after the separation of a lower stage rocket 1, said extendable nozzle mechanism characterized by comprising:
 - a coupling mechanism 7 disposed at a front end portion of said lower stage rocket 1;
 - a rocket engine 4 having a nozzle portion 6 provided with a latch mechanism 15 at a rear end outer circumferential wall and with an interconnecting surface 9, said rocket engine 4 being coupled with a rear end of said upper stage rocket 2; and
 - a highly expandable nozzle 5 having, at a rear end portion, a fastening portion which is coupled with said coupling device 7 in said retracted condition and having, at a front end portion, a small diameter portion 8 which is brought into sliding contact with an outer circumferential wall of said nozzle portion 6 to release a coupling between said coupling 7 and said fastening portion to engage with said

interconnecting surface 9 during a shifting operation from said retracted condition to said operative condition.

2. The extendable nozzle mechanism according to claim 1, wherein said coupling mechanism 7 is fixed to the front end portion of said lower stage rocket engine 1, and said coupling mechanism 7 comprises an annular support 21 formed of an elastic material at least at its circumferential edge portion, said fastening portion being an inner circumferential wall formed at the rear end of said highly expandable nozzle 5 and coupled to said support 21.
3. The extendable nozzle mechanism according to claim 1, wherein said coupling mechanism 7 is fixed to the front end portion of said lower stage rocket engine 1, and said coupling mechanism 7 comprises an annular grooved support 24 with a recess 23 at its circumferential edge portion, said grooved support 24 being made of elastic material, said fastening portion including inner and outer circumferential walls of a rear end circumferential edge of said highly expandable nozzle 5 inserted into said groove.
4. The extendable nozzle mechanism according to claim 1, wherein said coupling mechanism 7 is a clamping mechanism 25 including two rods 27, 29 pivoted at first ends to the front end portion of said lower stage rocket 1, rollers 26 provided at second ends of said rods 27, 29, and a spring member 28 interposed between central portions of said rods 27, 29, said fastening portion being inner and outer circumferential walls of the rear end circumferential edge of said highly expandable nozzle 5 inserted in between said rollers of said clamping mechanism 25.
5. The extendable nozzle mechanism according to claim 1, wherein said coupling mechanism 7 is a coupling bracket 29 fixed at one end to the front end portion of said lower stage rocket 1 and provided with a cutting slit at its central portion, and said fastening portion is the rear end circumferential edge of said highly expandable nozzle 5 for fixing the other end of said coupling bracket 29.
6. An extendable nozzle mechanism for a rocket engine, used for separating from said rocket engine 4 a highly expandable nozzle 5 coupled at a front end portion to a rear end portion of said rocket engine 4 and bringing a retracted condition where said highly expandable nozzle

5 is loosely engaged around an outer periphery of said rocket engine 4 into an operative condition of said rocket engine 4, said extendable nozzle mechanism characterized in that said highly expandable nozzle 5 is extended to a regular position by utilizing a momentum of an object to be separated and abolished during the propelling operation of said rocket, said highly expandable nozzle 5 being coupled through wires 30 to said object to be separated and abolished.

7. An extendable nozzle mechanism for a rocket engine, used for separating from said rocket engine 4 a highly expandable nozzle 5 coupled at a front end portion to a rear end portion of said rocket engine 4 and bringing a retracted condition where said highly expandable nozzle 5 is loosely engaged around an outer periphery of said rocket engine 4 into an operative condition of said rocket engine 4, said extendable nozzle mechanism characterized in that guide rails 18 in parallel with said engine 4 are provided to at least one of a rear end portion of a rocket 2 on which said rocket engine 4 is mounted and an end portion of an object 1, 1' to be separated, and travelling rollers 19 which travel along said guide rails 18 are provided on the other.

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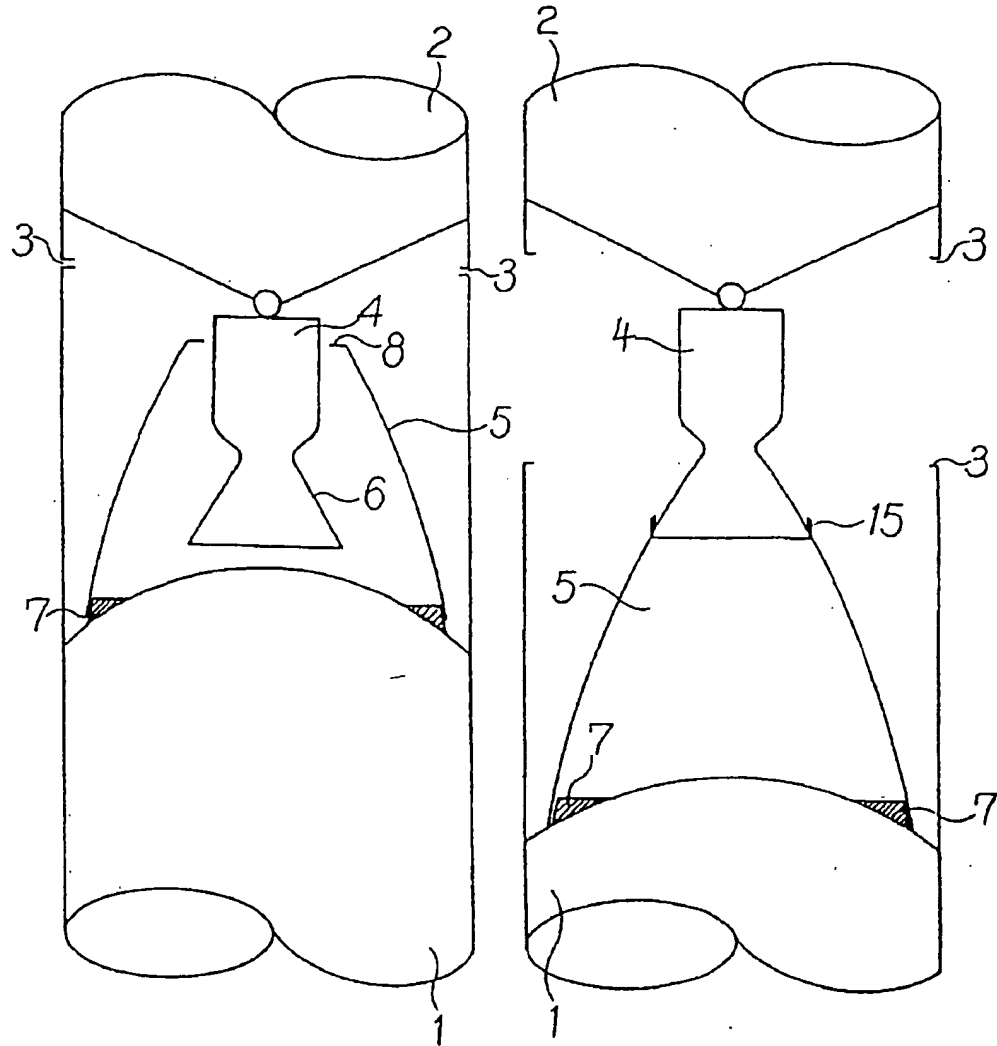


Fig. 1(A)

Fig. 1(B)

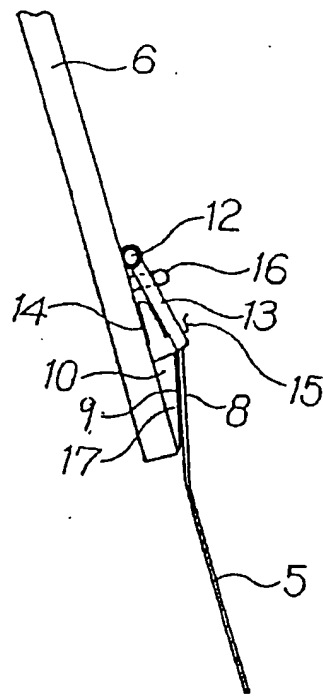


Fig. 2

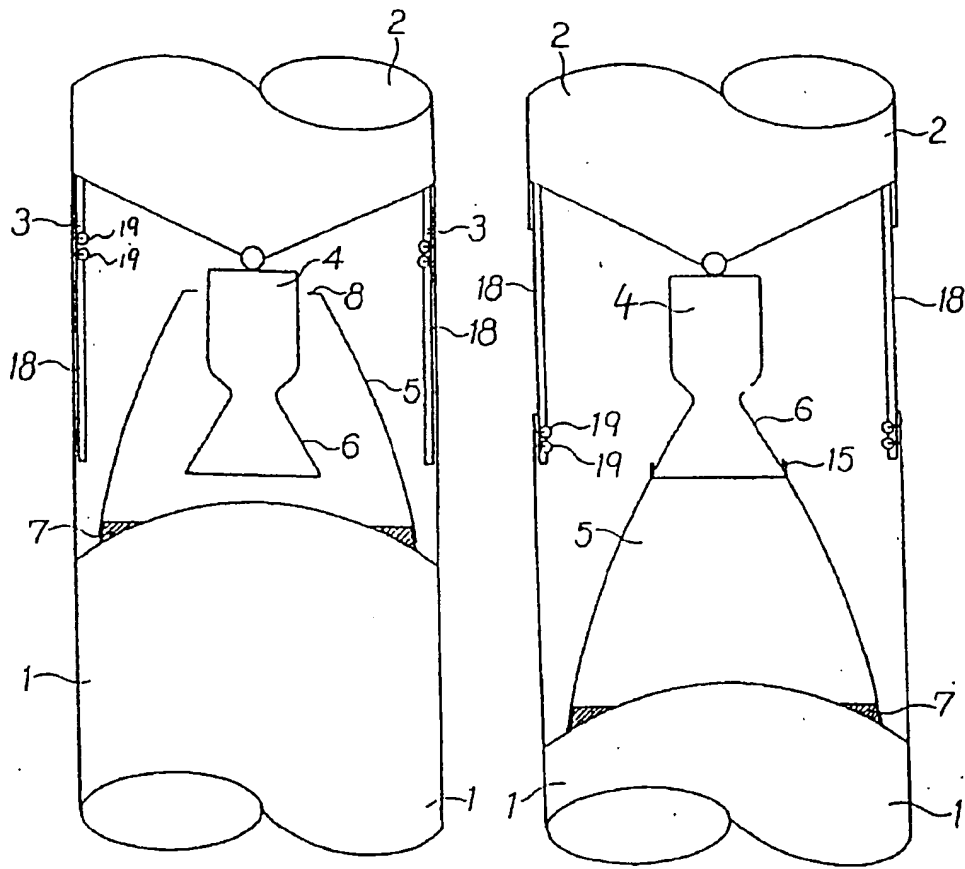


Fig. 3 (A)

Fig. 3 (B)

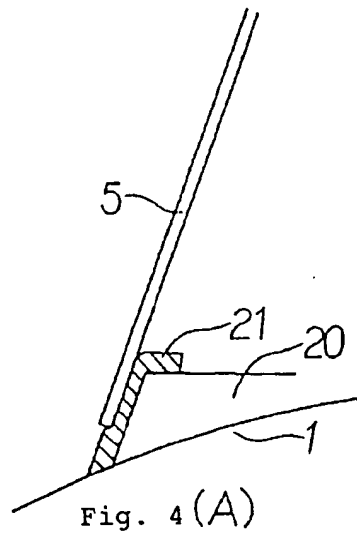


Fig. 4 (A)

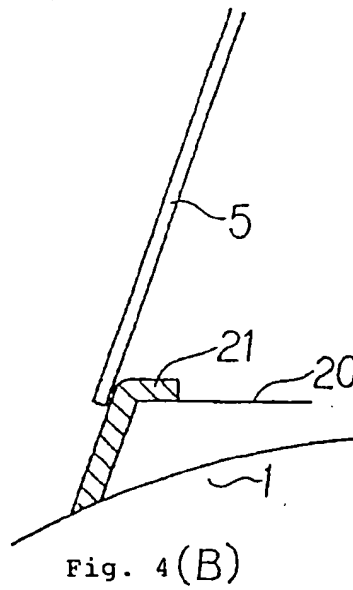
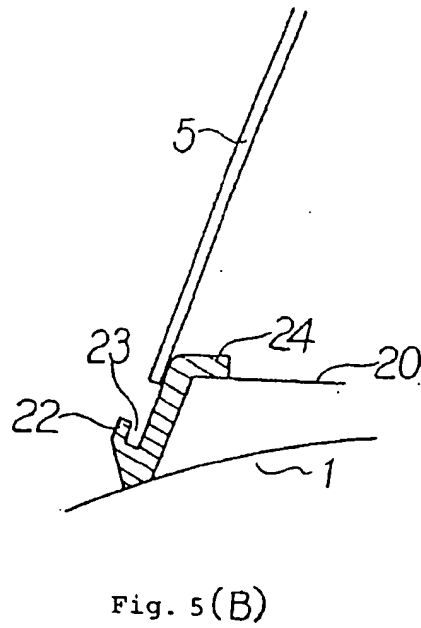
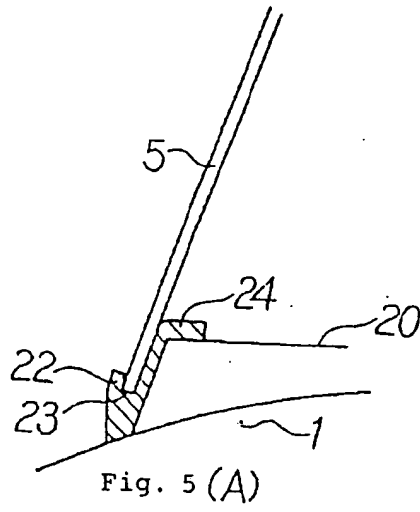


Fig. 4 (B)



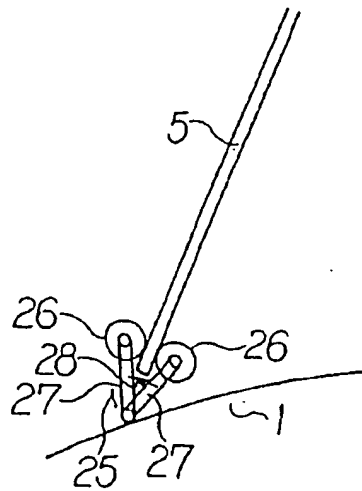


Fig. 6 (A)

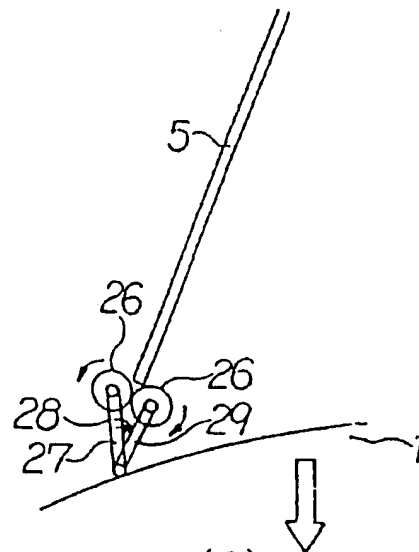


Fig. 6 (B)

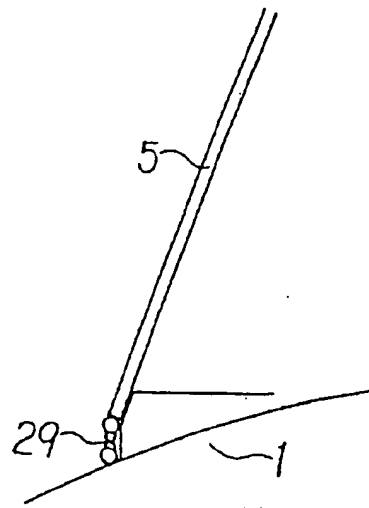


Fig. 7 (A)

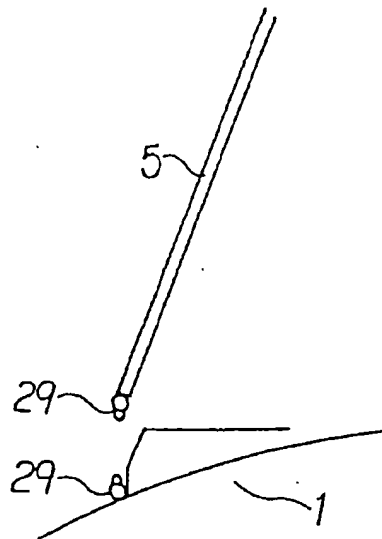


Fig. 7(B)

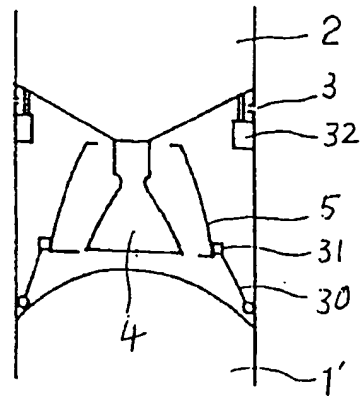


Fig. 8(A)

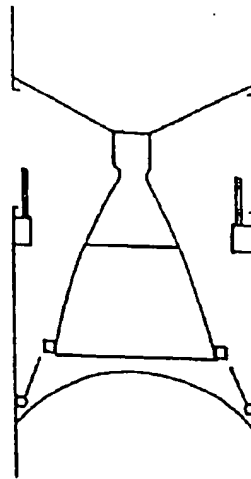


Fig. 8(B)

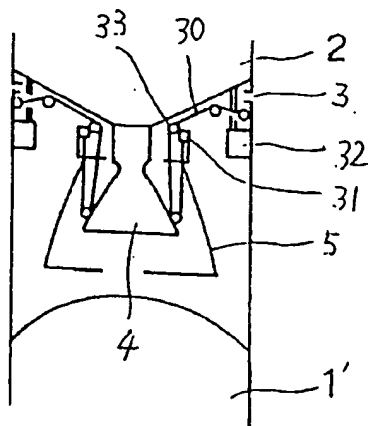


Fig. 9 (A)

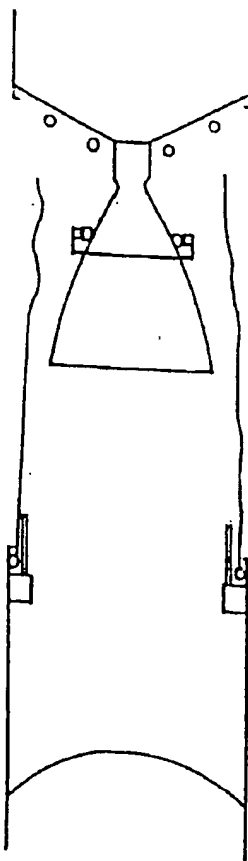


Fig. 9 (B)

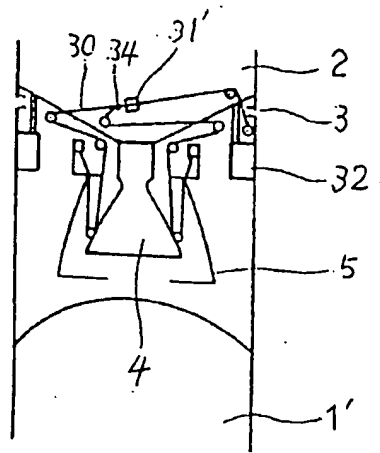


Fig. 10(A)

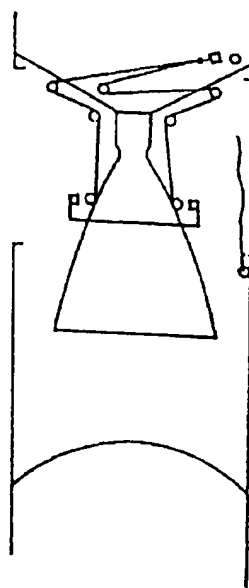


Fig. 10(B)

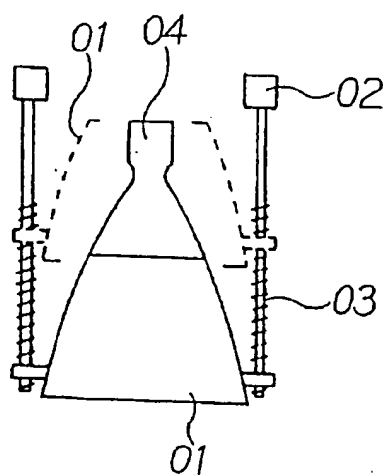


Fig. 11

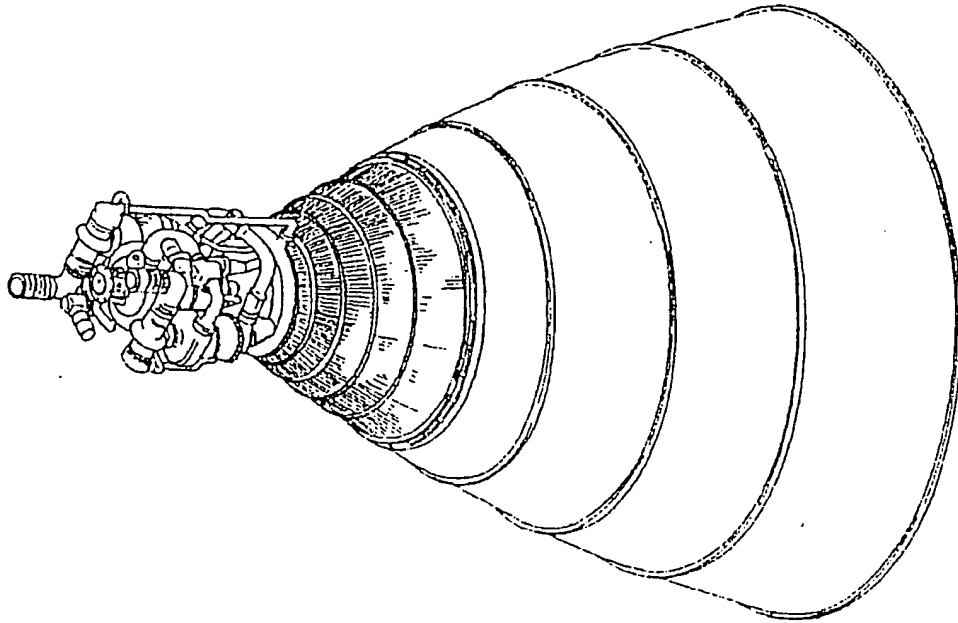


Fig. 12 (B)

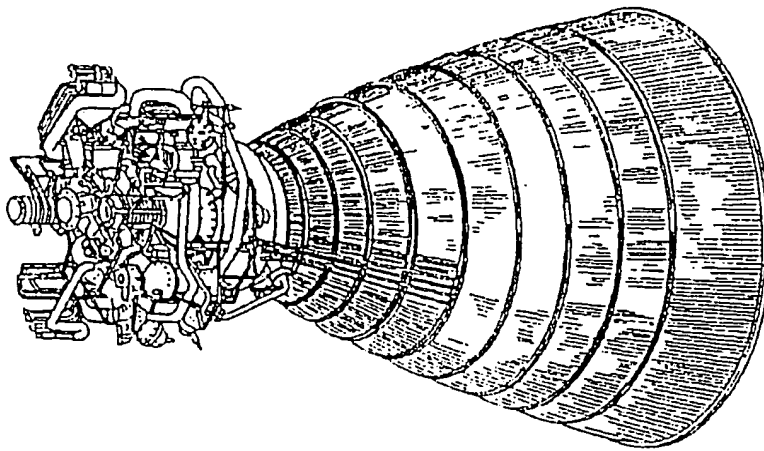


Fig. 12 (A)



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 94 11 9659

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X A A A A	US-A-3 561 679 (LAGER) * the whole document * --- EP-A-0 173 009 (ROCKWELL) --- PATENT ABSTRACTS OF JAPAN vol. 9, no. 183 (M-400) (1906) 30 July 1985 & JP-A-60 050 259 (NISSAN) * abstract * --- GB-A-2 029 511 (HERCULES) -----	1 5-7	F02K9/97 F42B15/36
			TECHNICAL FIELDS SEARCHED (Int.Cl.6)
			F02K F42B
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 31 March 1995	Examiner Iverus, D
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